TITLE
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Constraints on the $\Omega_M - \Omega_\Lambda$-plane from Elliptical Galaxy Counts ?

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Abstract. Here we present a pilot study into whether elliptical galaxy counts alone, can place a useful constraint on the $\Omega_M - \Omega_\Lambda$-plane. The elliptical galaxy counts are drawn from three surveys: The Millennium Galaxy Catalogue ($16 > B_{KPNO} > 20$), the B-band Parallel Survey ($20 > B_{AB} > 24$) and the Hubble Deep Fields ($23 > B_{AB} > 28$). The elliptical luminosity function used in the modeling was derived from a combination of the Millennium Galaxy Catalogue, the two-degree field galaxy redshift survey and the Sloan Digital Sky Survey ($M_*^{E/S0} = -19.90, \phi_*^{E/S0} = 0.0019$ Mpc^{-3} and $\alpha^{E/S0} = -0.75$ for $H_o = 75$km/s/Mpc). We adopt a benchmark model and tweak the various input parameters by their uncertainties to determine the impact upon the counts. We find that *if* the faint-end slope of the elliptical galaxy luminosity function is known to $\Delta\alpha < 0.1$, then over the magnitude range $16 < B < 23$ the counts depend most critically upon the cosmology, and can be used to place a weak constraint on the $\Omega_M - \Omega_\Lambda$-plane.

1. Introduction

Galaxy number-counts as a cosmological probe have been fraught with difficulties since the conception of the idea by Edwin Hubble in the 1930s (Hubble 1936). In a recent review Sandage (1997) provides an insightful historical overview of this topic. The concept itself was severely challenged by the work of Tinsley (1977) who showed that the faint galaxy number-counts depend more critically upon evolution than upon the cosmological model (at this time only zero-Λ models were being considered). In the 1990s even this was superseded by the faint blue galaxy problem (see Ellis 1997 for a recent review). It is therefore fair to say that in the lead up to the turn of the Millennium the use of galaxy number-counts as a cosmological probe was discredited. Nevertheless attempts were made and retrospectively may have provided the first tentative evidence for a positive cosmological constant (Yoshi & Peterson 1995).

Three factors make the possibility of a revival of galaxy number-counts credible, these are: morphological segregation of the faint galaxy population and in particular the extraction of ellipticals; advances in our understanding of the evolution (or rather non-evolution) of ellipticals (see summary by Peebles in these proceedings); and the advent of Λ which dramatically broadens the impact of the cosmology upon the counts.

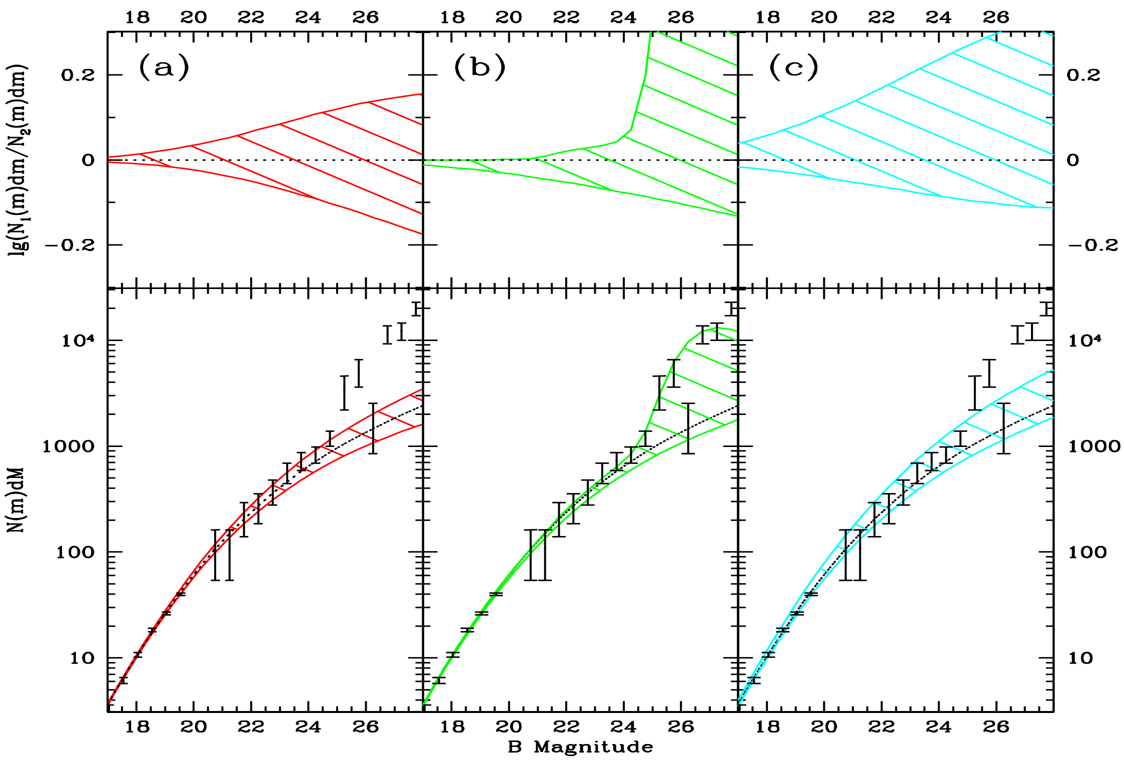

Figure 1. The three panels show elliptical galaxy number-count data and models (lower) and the same number-count models with the $[\Omega_M = 0.3, \Omega_\Lambda = 0.0]$-benchmark model divided out (upper). (a) shows the sensitivity of the models to variations in the cosmology ($[\Omega_M = 0.3, \Omega_\Lambda = 0.7]$, to $[\Omega_M = 1.0, \Omega_\Lambda = 0.0]$), (b) the sensitivity to the evolution ($[e(z) = (1 + z), n(z) = 0]$ to $[e(z) = 0, n(z) = (1 + z)^{-0.3}]$) and (c) the sensitivity to the faint-end slope $[\alpha = -0.5]$ to $[\alpha = -1.0]$).

2. The Data

Fig. 1 shows the published elliptical count data drawn from three surveys. The Millennium Galaxy Survey (MGC; Lemon et al 2002); the B-band parallel survey (BBPAR; Cohen et al 2002) and the Hubble Deep Fields (HDFs; Driver et al 1998). The MGC is a ground-based survey over 35 sq degrees along the equatorial strip, conducted at the Isaac Newton Telescope using the Wide Field Camera (see Lemon et al 2002). The B-band parallel survey consists of WFPC2 F450W observations drawn from the HST archive spanning ~ 0.04 sq degrees (Cohen et al 2002). Finally the deepest data comprises the Hubble Deep Fields and the deep field 53W02 (Driver et al 1998) spanning ~ 0.007 sq degrees. While these surveys are independent bodies of work the techniques applied are not. In particular the morphological classifications have been made using the identical ANN classifier along with the same set of eyeballs to verify the accuracy. This is crucial as it is vitally important for the classification criterion to be uniform across the entire magnitude range.

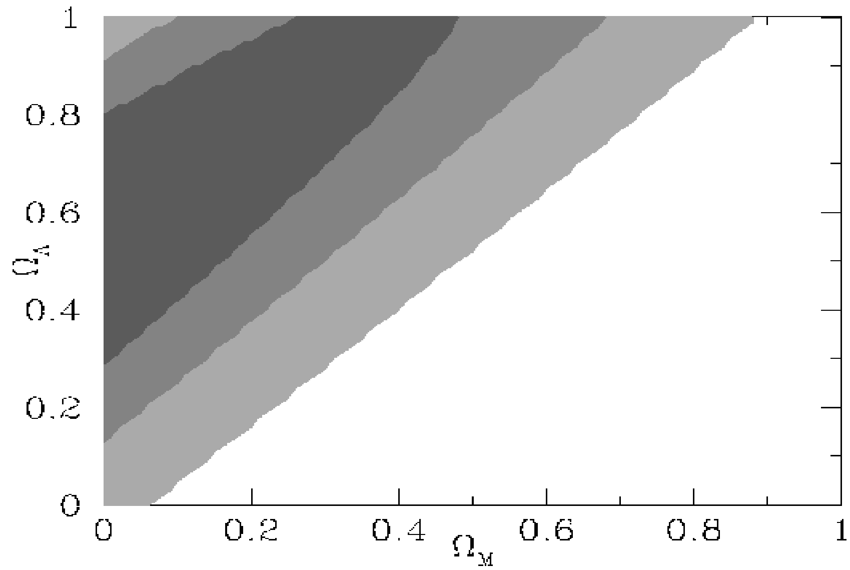

Figure 2. The 1-,2- and 3-σ χ^2-contours in the $\Omega_M - \Omega_\Lambda$-plane for the standard benchmark model (see text), i.e., zero net evolution

3. Constraining $\Omega_\Lambda - \Omega_{Matter}$

To model the elliptical counts we require 8 parameters ($\phi_*, M_*, \alpha, e(z), n(z), k(z), \Omega_M, \Omega_\Lambda$), by marginalising over ϕ_* and solving for $\Omega_M - \Omega_\Lambda$ this requires 5 known parameters. Here we adopt as our benchmark model the following ($H_o = 75$km/s/Mpc):

$$M_* = -19.9, \alpha = -0.75, e(z) = 0, n(z) = 0,\ k(z) = 4z + 1.5z^2 - 1.3z^3 + 0.27z^4$$

Fig. 1 shows the assembled galaxy number-counts along with our benchmark model (dotted line). We now perturb the benchmark model as indicated in the figure caption to show how the models depend upon: Fig.1(a), the cosmology; Fig.1(b), the evolutionary model (pure-luminosity or number-density); and Fig.1(c), the faint-end slope of the local luminosity function. The upper panels show the same with the benchmark model divided out. At very faint magnitudes ($B > 24$) mags the uncertainty in the evolution entirely dominates the galaxy counts. At intermediate and bright magnitudes it is the uncertainty in α which dominates. However pressing further we find that if $\Delta\alpha < 0.1$ then it is the cosmology which dominate the counts over the range $16 < B < 23$ mags. It should therefore be viable to place a constraint on the $\Omega_M - \Omega_\Lambda$-plane using *bright* morphological galaxy counts. Fig. 2 shows the resulting χ^2 1-, 2- and 3-σ regions in the $\Omega_M - \Omega_\Lambda$-plane for the benchmark model (i.e., M_*, α, $k(z), e(z)$ and $n(z)$ fixed to the values above) and marginalising over ϕ_*. The benchmark counts clearly favour a non-zero cosmological constant but how much is this due to the adoption of the five fixed parameters. Marginalising over all parameters requires extensive supercomputer time currently not available, however in Fig. 3 we show the results for three perturbations of our benchmark model to indicate the likely impact of some of these parameters upon the results. These perturbations to the benchmark model are shown below:

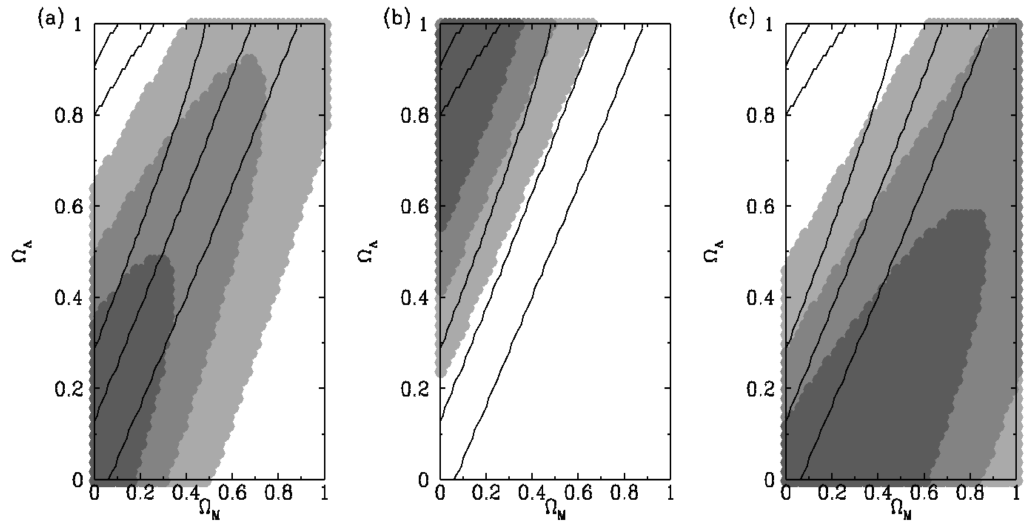

Figure 3. The $\Omega_M - \Omega_\Lambda$-plane for our three perturbations of the benchmark model (see text). Lines indicate contours from Fig 2.

Perturbation 1 (Fig 3a): $e(z) = (1+z)^1$, a pure-luminosity evolution model
Perturbation 2 (Fig 3b): $n(z) = (1+z)^{-0.3}$, a number-density evolution model
Perturbation 3 (Fig 3c): $\alpha = -1.0$, an uncertainty in α

It can be seen that the change from pure-luminosity evolution, to zero-evolution, to number-density evolution mimics Λ. I.e., if galaxies were brighter in the past one needs to reduce the volume element in order to keep the galaxy-counts constant etc. Curiously neither extreme allows for an $\Omega_M = 1$ universe. More worrisome however is the critical dependency on α. Current published values range from $\alpha = -0.5$ to $\alpha = -1$ and until it is pinned down an $\Omega_M = 1$ universe is allowed. Hence our conclusion is that it is the uncertainty in the local luminosity function parameters and in particular α which currently prevents a serious credible constraint on the $\Omega_M - \Omega_\Lambda$-plane.

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